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South Wales
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In accordance with the Patents (Companies Re-registration) Rules 1982, if a company named in this certificate and any accompanying documents has re-registered under the Companies Act 1980 with the same name as that with which it was registered immediately before re-registration save for the substitution as, or inclusion as, the last part of the name of the words "public limited company" or their equivalents in Welsh, references to the name of the company in this certificate and any accompanying documents shall be treated as references to the name with which it is so re-registered.

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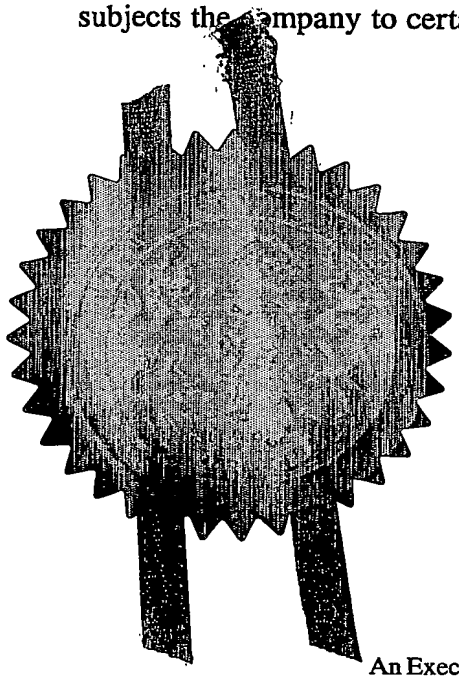


Signed

Dated 9 October 2003

PRIORITY DOCUMENT
SUBMITTED OR TRANSMITTED IN COMPLIANCE WITH RULE 17.1(a) OR (b)

Patents Form 1/77

[redacted] t 1977

THE PATENT OFFICE
28 AUG 2003
NEWPORT

The Patent Office

28AUG03 E833261-1 C69640
P01/7700 0.00-0320124.1

Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
South Wales
NP10 8QQ

1. Your reference

PDGW/LUEL/QUIN

2. Patent application number
(The Patent Office will fill this part in)

0320124.1

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

SEE CONTINUATION SHEET

Patents ADP number *(if you know it)*

① 8447307001
② 8457335001

If the applicant is a corporate body, give the country/state of its incorporation

4. Title of the invention

PROJECTILE MONITORING SYSTEM

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

i.p.21 Limited

Norwich Research Park
Colney
NORWICH NR4 7UT

Patents ADP number *(if you know it)*

8143653001

6. Priority: Complete this section if you are declaring priority from one or more earlier patent applications, filed in the last 12 months.

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
GB	0220364.4	03/SEPT/2002

7. Divisionals, etc: Complete this section only if this application is a divisional application or resulted from an entitlement dispute (see note f)

Number of earlier UK application	Date of filing *(day / month / year)*

8. Is a Patents Form 7/77 (Statement of inventorship and of right to grant of a patent) required in support of this request?

YES

Answer YES if:

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.

Otherwise answer NO (See note d)

Patents Form 1/77

[redacted]companying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form:

Continuation sheets of this form	0
Description	6
Claim(s)	1
Abstract	0
Drawing(s)	2 +2

10. If you are also filing any of the following, state how many against each item.

Priority documents	
Translations of priority documents	
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	
Request for a preliminary examination and search (Patents Form 9/77)	
Request for a substantive examination (Patents Form 10/77)	
Any other documents (please specify)	

11. I/We request the grant of a patent on the basis of this application.

Signature(s) ip21 Limited by P Wilson Date 26/08/03

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom

PETER WILSON 01603 457008
peterwilson@ip21.co.uk

Warning

After an application for a patent has been filed, the Comptroller of the Patent Office will consider whether publication or communication of the invention should be prohibited or restricted under Section 22 of the Patents Act 1977. You will be informed if it is necessary to prohibit or restrict your invention in this way. Furthermore, if you live in the United Kingdom, Section 23 of the Patents Act 1977 stops you from applying for a patent abroad without first getting written permission from the Patent Office unless an application has been filed at least 6 weeks beforehand in the United Kingdom for a patent for the same invention and either no direction prohibiting publication or communication has been given, or any such direction has been revoked.

Notes

a) If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.

b) Write your answers in capital letters using black ink or you may type them.

c) If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.

d) If you have answered YES in part 8, a Patents Form 7/77 will need to be filed.

e) Once you have filled in the form you must remember to sign and date it.

f) Part 7 should only be completed when a divisional application is being made under section 15(4), or when an application is being made under section 8(3), 12(6) or 37(4) following an entitlement dispute. By completing part 7 you are requesting that this application takes the same filing date as an earlier UK application. If you want the new application to have the same priority date(s) as the earlier UK application, you should also complete part 6 with the priority details.

Continuation of Patents Form 1/77

3. Name, address and postcode of each of the two applicants

(1)

Loughborough University Enterprises Limited
Rutland Hall
Loughborough University
Loughborough
Leicestershire
LE11 3TU

Corporate body, incorporated in GB

(2)

Christopher Sumpter
1 Kevern Close
Wigston
Leicester
LE18 2GR

Figure 1

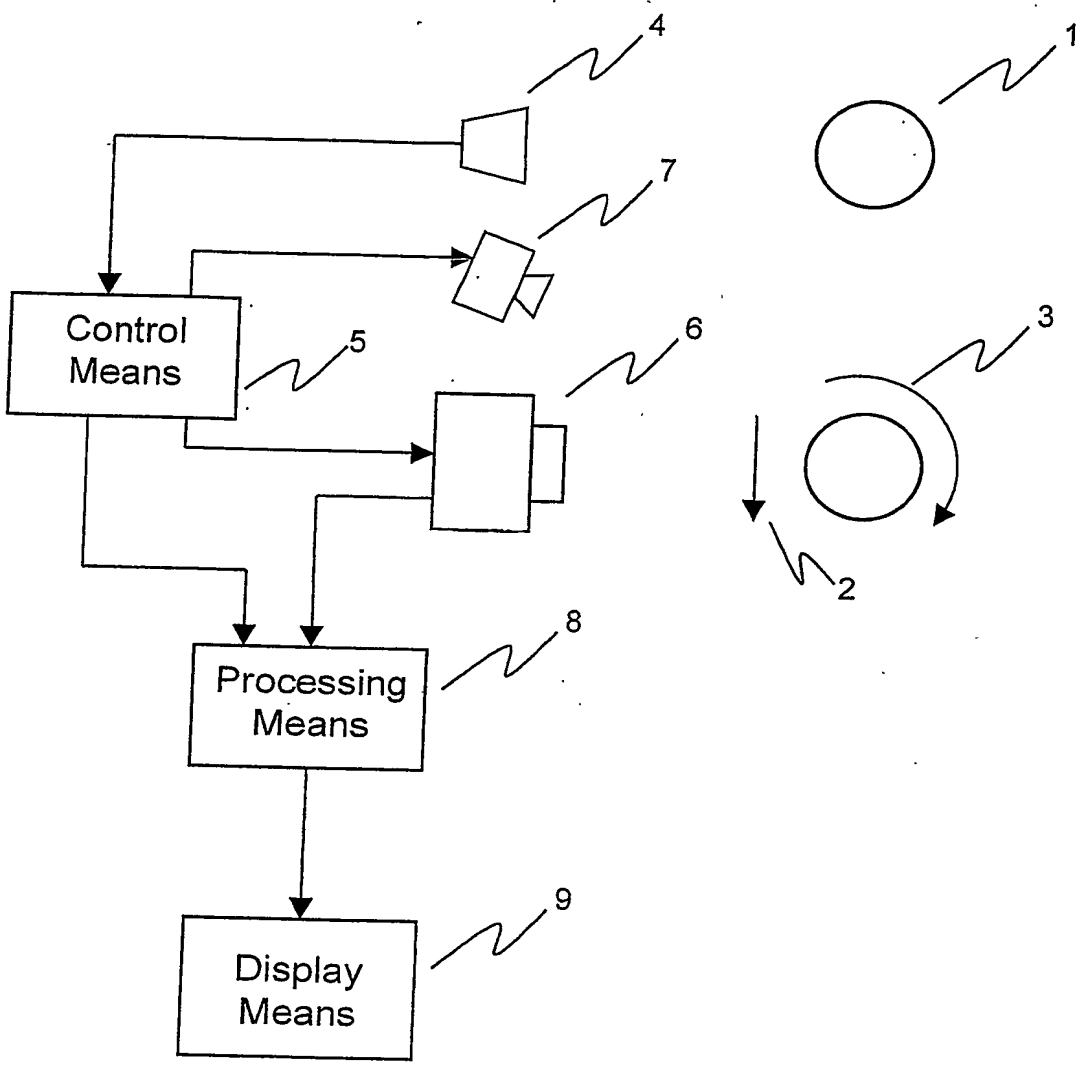
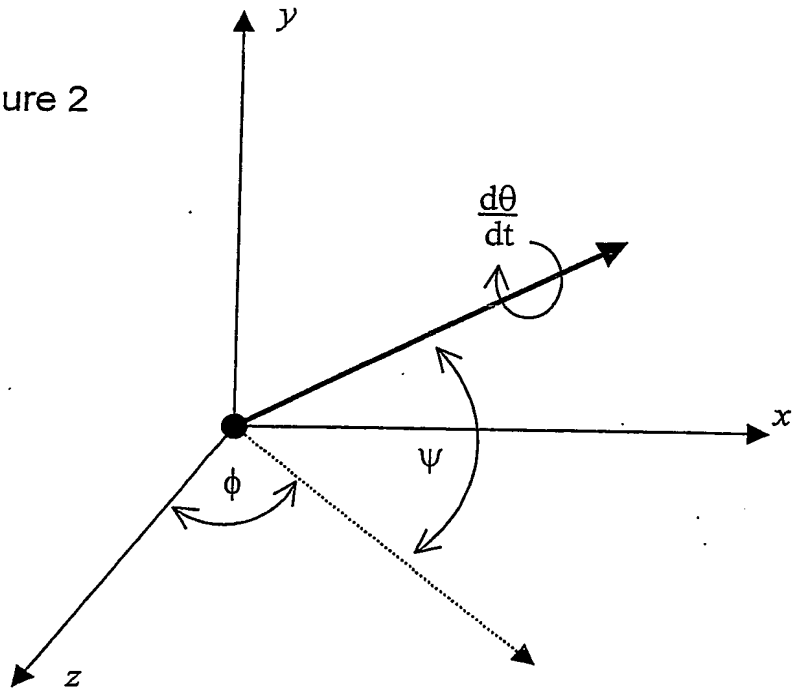


Figure 2



PROJECTILE MONITORING SYSTEM

Field of the Invention

The invention relates to a system for monitoring movement imparted to a projectile, and particularly to projectiles used in a sporting context, to enable the projectiles translational and rotational movement in space to be determined.

Review of the Art known to the Applicant

Many sports involve the use of projectiles during the course of play. In most cases these are balls, usually approximately spherical in shape, and of a variety of sizes. Some sports such as rugby use non-spherical balls, and others such as ice hockey and discus-throwing use essentially disc-shaped objects. A common feature in the practice of these sports is the importance of the spin on the projectile, for a number of reasons. By causing the ball to spin, a skilled player can make the ball curve in flight as a result of the induced pressure differential across the ball; this phenomenon is known as the Magnus effect. Spin can also be of importance to subsequent movement of the ball following impact, such as causing a golf ball to stop moving when it hits the green, causing a table tennis ball to rebound from the table at unpredictable angles, and affecting the movement of cue and target balls in sports such as snooker and billiards.

Such is the central importance of spin to many ball sports that it is useful to be able to measure the rate and axis of spin of a ball. This can be used in the training of sports people, and can be helpful when designing sports equipment such as shoes, clubs, bats and, of course, the balls themselves.

Several approaches to measuring the spin rate of balls have been proposed, but all suffer a number of disadvantages. US Patent No. 6157898 discloses a device for measuring the movement, including spin, of a movable object such as a sports ball. The method requires that a radio transmitter is attached to the object under study. This highly technological solution to the problem clearly has drawbacks in terms of cost, and the additional device secured to the object is likely to effect the object's behaviour in flight.

The UK Patent Application No. GB2319834, and US Patent No. 5798833 describe a machine and method for measuring the rotational speed of a flying object. The device operates by analysing light reflected from a flying object that has been treated to have a reflective mark on it. The frequency of fluctuations of the reflected light is then used to estimate the rotational speed of the object. A drawback of this technique is that it requires an extended period of measurement in order to determine the fluctuation frequency, and gives no indication of the axis of rotation.

United States Patent No. 4136387 describes a system for measuring the displacement of golf club heads in use, and also the movement of golf balls following impact with the club. The specification discloses the use of at least three non-collinear spots on the object, and requires the use of at least two electro-optical kinematic monitors to detect the positions of the spots at two closely spaced points in time. The disadvantage of such as ball-marking scheme and measurement system is the requirement for multiple sensors, and the non-uniqueness of the pattern of spots following rotational movement.

United States Patent No. 6390934 describes a method of image processing of paint dots on golf balls. This patent is primarily concerned with the image processing method, but discloses the use of at least three, and preferably at least six dots on the golf ball, preferably arranged in a pentagonal pattern. Again, this approach has the disadvantage of the possibility of non-unique patterns of dots following a rotational translation.

The common feature of non-uniqueness of patterns of dots on balls following rotational movement has the consequence that situations might arise where it is impossible to determine whether, and if so how much, rotation has occurred by inspection of two images spaced apart in time.

Other approaches of measuring the spin on balls known to the applicants include the use of a 'Great Circle' marking (i.e. a single 'equator'). This has the disadvantage that the system is unable to detect spin around an axis perpendicular to the plane of the great circle. A development of this technique using three orthogonal Great Circles has also been proposed. This approach again has disadvantages such as the existence of a 90° symmetry in the marking, thus preventing the measurement of rotation if the ball rotates more than this angle between subsequent images.

Accordingly it is an object of the present invention to provide a system for monitoring the movement imparted to a projectile, including but not limited to sports balls, that determines both the translational and rotational movement in space of a projectile following its launch.

Summary of the Invention

The invention provides a system for monitoring movement imparted to a projectile, marked according to UK Patent Application GB0220364.4, comprising: launch detection means to detect the moment of launch of said projectile; image acquisition means to acquire images of said projectile, in flight; control means to activate said image acquisition means in reaction to the moment of launch of said projectile; processing means capable of determining the velocity and spin of said projectile by comparison of a plurality of images so acquired, and adapted to do so by virtue of being cognisant of the essentials of the marking method embodied in said projectile; and display means to display the velocity and spin to a user, in use.

The invention will be described with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram of the system for monitoring movement imparted to a projectile and

Figure 2 illustrates the spin axes.

Description of the Preferred Embodiment

The preferred embodiment of the invention comprises a projectile marked according to our co-pending UK patent application number GB0220364.4 wherein the marking comprises a series of panels.

With reference to Figure 1,in this embodiment, the projectile 1 of interest is a football (UK soccer ball) whose surface is marked with a number of coloured panels. In use, a user imparts movement to the projectile 1, for example by kicking the football, thus imparting both translational and rotational movement to the ball indicated by the arrows 2 and 3. The launch of the projectile 1 is detected by the launch detection means 4. In this embodiment, this means comprises a sound trigger, i.e. a microphone device. The launch detection means 4 sends a signal through the control means 5, which may conveniently comprise either a computer system with appropriate hardware, itself known in the art, or another electronic or electrical device. The control means 5 controls a 30 frames per second digital camera 6 with a 1/8000 second shutter speed. In this embodiment, this choice of camera and shutter speed is appropriate for the range of translational and rotational movements imparted to a football by a skilled player. The control means 5 also trigger a flash gun 7. The control means has a time delay between detection of launch of the projectile 1 and triggering one or more flash guns 7. For the case of a football-monitoring device, a typical time delay will be around 70 ms.

Following the acquisition of a series of images of the moving projectile 1 the images are transmitted to the processing means 8. The processing means 8 in this embodiment resides on the same computer as the control means 5, but could, if required, be separate.

The processing means selects two images from those acquired, each containing an image of the projectile 1, and separated in time. At the typical frame rate described above, and

at a kicking speed of 35 m/s (a typical maximum velocity for a football kicked by a professional player) successive frames will show images of the ball approximately 1 metre apart.

By virtue of the unique arrangement of panels on the projectile 1, analysis of the translational and rotational movement of the projectile 1 may be effected by image analysis. A suitable algorithm for such analysis is as follows:

Two images are selected from those collected, each going the projectile within the same overall frame of view. These images represent a moving foreground object with a substantially static background, subtraction of the images one from another will eliminate the background, and identify the position of the moving projectile. This subtraction methodology is often referred to as "differencing" in the field of image analysis. The resultant images can be enhanced and cleaned by use of standard image analysis techniques, such as shadow removal and filtering. The known size of the projectile may be used to determine the scaling of the image. From a knowledge of this scaling, and the orientation of the images, the velocity component in a plane parallel to the plane of the camera may thus be determined. The change in the size in the image of the projectile from one frame to another may be used to obtain the velocity component of the projectile in the direction perpendicular to the plane of the camera. These calculations thus give a measure of the speed and angle (i.e. the velocity) of the projectile at launch.

Having identified the position of the projectiles in the two images by the subtraction described above, these may be used to identify, and therefore construct a mask to identify the areas of interest in the original images. Where, as in this embodiment, the projectile is marked with a series of coloured panels, colour analysis and segmentation of the image may readily be applied to identify the central location of each panel visible, its colour identification, and its area. This will provide an array of six or seven (x, y) co-ordinates, areas and colours.

The largest visible area is likely to be that closest to the camera, and therefore have the most accurate position and area data. The list of co-ordinates and associated data may therefore be sorted on the basis of this area.

From knowledge of the location of each of the coloured panels on the projectile a look-up table may be constructed containing the 3-D co-ordinates of the centres of the panels (32 in the case of a truncated icosahedron that is often used to approximate a spherical football). This table represents an arbitrary reference frame within which rotational translations of the projectile may be defined. From the table, a matrix (32 x 32 for the truncated icosahedron) of chordal distances (The "Chordal Distance Matrix") between the centre points of the panels may be constructed, together with the colour reference of each panel.

From the image analysis, a table of panel locations may be constructed. The centre point of each visible panel (typically six or seven panels for a truncated icosahedron) as projected onto the image plane (x_i, y_i) may be located by standard image analysis techniques. Then, using a knowledge of the radius of the projectile, and the position of the projected centre points (x_i, y_i) with respect to the outline of the projectile, the true 3-dimensional coordinates of the centre points (x, y, z) may be calculated, and the chordal distances between each of the panel centre points calculated.

A search of this Chordal Distance Matrix for matching colour references and chordal distances will identify each of the visible panels with respect to the marking scheme of the projectile.

Having identified the identity and location of the panels, the unique orientation of the projectile in space for each of the two images may then be calculated. Matrix algebra may be used to transform an original (arbitrary) reference frame to the new observed reference frame of the projectile. In this way, both the rotational rate and the axis of the rotation of the projectile may be determined. By reference to Figure 2, this may be conveniently expressed by reference to an orthogonal reference frame (x, y, z) by two angles φ and ψ, and an angular rotational rate ($d\theta/dt$).

CLAIMS

1. A system for monitoring movement imparted to a projectile, marked according to UK Patent Application GB0220364.4, comprising:

launch detection means to detect the moment of launch of said projectile;

image acquisition means to acquire images of said projectile, in flight;

control means to activate said image acquisition means in reaction to the moment of launch of said projectile;

processing means capable of determining the velocity and spin of said projectile by comparison of a plurality of images so acquired, and adapted to do so by virtue of being cognisant of the essentials of the marking method embodied in said projectile; and

display means to display the velocity and spin to a user, in use.